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Observations on *Pseudosinella petterseni* and *Pseudosinella alba* (Collembola: *Entomobryidae*) in Eastern Canada

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With 2 figures in the text

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1. Introduction

Pseudosinella petterseni was first described from Europe by Börner (1901). Guthrie (1903) and Folsom (1924) redescribed the same species from Minnesota and from Massachusetts, New York, Indiana and Illinois under the names *Cyphodeirus albinus* and *Lepidocyrtus violentus* respectively. Mills (1934) transferred the latter to the genus *Pseudosinella* and recorded it — as *P. violenta* (Folsom) — from Iowa. Later, Maynard (1951) synonymized it with *P. petterseni*. Another synonym, *Pseudosinella höfti* (Schäffer, 1896), is given by Denis (1949), but Gisin (1960) lists *höfti* as a synonym of *Sinella coeca* (Schött, 1896).

P. petterseni is a very widely distributed species. In Europe it has been recorded from Ireland, Spain, Denmark, Germany, Austria, Switzerland, and Czechoslovakia (Gisin 1960, Nosek 1962); in North America it has been recorded in the United States from the various states already mentioned and from Connecticut, North Carolina, Missouri, Tennessee, Arkansas, Louisiana, Texas, Utah, California and Washington (Maynard 1951; Bellinger 1954; Christiansen 1960) and, in Canada, from Ontario (Chatham, Belleville and Kingston) (James 1933), although not hitherto from Qeubec. In Central America it has been recorded from Costa Rica (Denis 1931).

P. petterseni belongs to the soil fauna and is common under logs or stones; it is also abundant in greenhouses. Like other Collembola with a dense scaly covering, this species may be found associated with soil that is rather dry (Folsom 1924). Folsom further states

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that, "it occurs often in company with ants of various species, especially under stones embedded in the ground." CHRISTIANSEN (1960) recorded it from caves in Texas and Iowa. At Macdonald College, Ste. Anne de Bellevue, Quebec, it has been collected from the thick litter layer and mull-type soil under sugar-maple trees (*Acer saccharophorum* K. KOCH) in the Morgan Arboretum.

Some published information on the biology of the species is available. DAVIS and HARRIS (1936), using the name *P. violenta*, described the effect of humidity on its life stages at 25, 30, 34 and 36.7 °C., and BELLINGER (1954) has studied its vertical distribution in Connecticut soil. SPENCER and STRACENER (1929, 1930) have indicated that *Lepidocyrtus violentus* [= *P. petterseni*] makes pits in the roots of sugar-cane and causes damage by gnawing off the lateral roots, retarding cane-sprout growth and causing a marked reduction in the percentage of sucrose. FLOR (1930) also refers to the species as being associated with root-rot of sugar-cane. INGRAM (1931) observed that it will graze on the root-hairs of the same crop, and FOLSOM (1933) has reported it as damaging the roots of beets.

Pseudosinella alba was described (in the genus *Lepidocyrtus*) from Massachusetts by PACKARD (1873). Elsewhere in North America, it has been recorded, as *L. alba*, for New York by FOLSOM (1928), and for Ontario (CHATHAM, BELLEVILLE, GRIMSBY and CRIEFF HILLS) by JAMES (1933). SCHÄFFER (1900) referred to European material of this species as *Sira* (*Pseudosinella*) *alba*, and BÖRNER (1901) used the name *Pseudosinella alba*. MILLS (1934) was responsible for applying the latter to earlier North American records of the species, and reported it from Minnesota, Ohio and Tennessee as well as from the two states already mentioned; BELLINGER (1954) notes that it occurs in Connecticut. Like *P. petterseni*, *P. alba* is thus widely distributed in North America, although not previously recorded from Quebec. It also occurs throughout most of Europe (including Finland, England, and Czechoslovakia), except for the arctic regions, and is known from Australia (cf. GISIN 1944, 1960; NOSEK 1962). *Tullbergia ocellata* LIE-PETTERSEN, 1896, is listed as a synonym by GISIN (1960).

P. alba is a common species occurring under stones on sandy soil (MAYNARD 1951) and in the soil under conifer stands (BELLINGER 1954). CHRISTIANSEN (1960) records it from caves in Minnesota and Tennessee. At Ste. Anne de Bellevue, Quebec, it has been extracted in large numbers from the same habitat as *P. petterseni*, many of the soil samples containing both species together.

Little seems to be known of the biology of *P. alba*, although BELLINGER (1954) has studied its vertical distribution in Connecticut along with that of *P. petterseni*. No economic importance has so far been attributed to this species.

2. Materials and Methods

In general, the materials employed and the methods used were the same as have already been described by SHARMA and KEVAN (1963 a) in their account of *Isotoma notabilis* SCHÄFFER.

The number of moults and the duration of the various instars prior to oviposition were studied by isolating young individuals, just after hatching, in groups of from 2 to 6, in small rearing cells (SHARMA and KEVAN 1963 a). Rearing was carried out at 11, 17 and 24 °C. At 17 °C., 7 cells were used in the case of *P. petterseni* and 6 for *P. alba*. At 11 and 24 °C., 6 and 7 cells respectively were used for each species. To observe the incubation period of each species at low temperatures, 30 eggs were placed in each of two rearing jars a few hours after they had been laid and then kept at 4 °C.

3. The Male Genital Plate

The general morphology of adult *P. petterseni* and *P. alba* has been adequately described (PACKARD 1873, BÖRNER 1901, FOLSOM 1928, MILLS 1934, GISIN 1960, CHRISTIANSEN 1960), but the male genital plate in the Entomobryidae (including *Pseudosinella*) has, until recently, been largely ignored. This is principally because of the difficulty in examining the

structure of the plate itself, which is very small, complex, and obscured by a dense body covering of large setae and scales, but also because of the scarcity of males in many species. Almost total ignorance of the organ in this family has resulted (CHRISTIANSEN 1958).

CHRISTIANSEN (1958) has, however, recently given a general description of the male genital plates of various genera of Entomobryidae, although he does not refer specifically to *P. petterseni* or to *P. alba*. DAVIS and HARRIS (1936) state that the male genital aperture of the former species (they use the name *P. violenta*) is situated on a setiferous biscuit-shaped papilla, but give no other details.

The female genital pore is merely a transverse slit guarded by anterior and posterior lips, devoid of setae; it is virtually identical in both the species studied.

In *Pseudosinella petterseni*, as in other Entomobryidae, the male genital plate, on which is situated the genital aperture, is located just behind the manubrium on the ventral side of the fifth abdominal segment. The plate is transverse and somewhat kidney-shaped, having a keyhole-like notch in the middle of the posterior margin, and at the anterior end of this notch lies the gonopore (Fig. 1d). Smooth, acuminate setae are more or less uniformly arranged in two concentric series on the genital plate: an inner series of 14—16 surround the gonopore and an outer series of 8—10 are placed submarginally (Fig. 1e, f). The genital plate measures 35 × 20 μ.

In *Pseudosinella alba* the subgenital plate is transversely oval, rather than reniform, but has a similar keyhole-like notch in the middle of the posterior margin to accommodate the gonopore. Numerous setae are arranged in three to four irregular concentric series between the gonopore and the margin of the plate. The latter measures 30 × 20 μ (Fig. 2d). The male genital plates of the two species differ in shape, size and number of setae and are thus quite distinct.

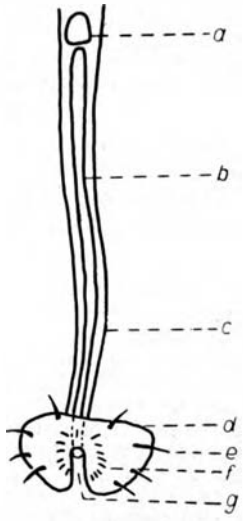

Fig. 1

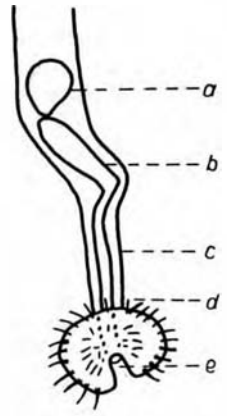

Fig. 2

Fig. 1. Spermatophore and male genital plate of *Pseudosinella petterseni*. a) Head of spermatophore, b) Tube of spermatophore, c) Ejaculatory duct, d) Genital plate, e) Setae of outer series, f) Setae of inner series, g) Genital pore. Magnification ca. 450×.

Fig. 2. Spermatophore and male genital plate of *Pseudosinella alba*. a) Head of spermatophore, b) Tube of spermatophore, c) Ejaculatory duct, d) Genital plate, e) Genital aperture. Magnification ca. 470×.

4. Spermatophore

As far as is known, males of arthropleone Collembola deposit their spermatophores on the substrate. SCHALLER (1954), for *Orchesella villosa* (GEOFFROY), describes the structure of the stalked spermatophore after deposition (see also SCHALLER 1962). As far as the writers are aware, the method of formation of the spermatophore and its position in the ejaculatory duct (the term used by LUBBOCK 1873) are still undescribed.

To ensure that males had insufficient time to discharge their spermatophores before they were killed, culture jars containing living *Pseudosinella petterseni* and *P. alba* were suddenly inverted over petri-dishes containing GISIN's fixative (see KEVAN 1955)[1]). In one specimen of *P. petterseni* mounted in Polyvinyl alcohol[2]) a structure, possibly a spermatophore, was clearly visible in the ejaculatory duct (Fig. 1). This structure consisted of two parts: a somewhat dome-shaped head 10 μ in length and a stalk 120 μ long. The stalk tapered posteriorly and ended bluntly. In the specimen referred to, the blunt end of the stalk lay just at the genital opening. It would seem that this male was about to deposit a spermatophore just before it was killed. There is, however, some doubt whether the structure observed was, in fact, a spermatophore since SCHALLER (in litt. 1962) is of the opinion that these are not properly formed until they are extruded, at least in those species with which he has worked.

In several specimens of *P. alba* a similar spermatophore-like structure was discovered. Its exact position before deposition was quite apparent from laterally mounted specimens and agreed with the above description. The head of the structure was, however, rather larger than in *P. petterseni* (15 μ long) and differed in shape, being somewhat drop-shaped. The stalk also differed in being shorter (only 70 μ) and broader at the anterior end, but it also tapered posteriorly and ended bluntly at the genital opening (Fig. 2).

On being deposited, the spermatophore of *Orchesella villosa*, as described by SCHALLER (1954), differs from the structure described above for *P. petterseni* and *P. alba* in the shape of the head, which is round instead of dome-shaped or drop-shaped. Since the spermatophores of Collembola are very minute and may be eaten by the males (SCHALLER 1962), they are difficult to detect in culture jars, and those of *P. petterseni and P. alba* were, in fact, never encountered.

5. Food

P. petterseni seems to be a rather unspecialized feeder. INGRAM (1931) reared this species on newly cut sugar-cane stalks and observed that a population of ten increased to two hundred and fifty in seven weeks. DAVIS and HARRIS (1936) have stated that their original colony of ten, when fed on soaked corn (maize), multiplied to 3,447 in a period of eight and a half weeks. In a second experiment, where four parched peanuts served as the only source of food, these authors found that individuals multiplied to 3,554 in seven and a half weeks. The peanuts were first pitted and then consumed.

In the present study *P. petterseni* was reared in the laboratory on commercial baker's yeast, on which it flourished satisfactorily at various temperatures. It was found, however, that the species was repelled by fungal mycelium and it avoided any part of the food so contaminated. This was also observed by DAVIS and HARRIS (1936).

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1) Ethyl alcohol (95 %), 750 m*l.*; Rectified ether, 250 m*l.*; Glacial acetic acid, 30 m*l.*; Formalin (40 % formaldehyde solution in water), 3 m*l.*

2) Polyvinyl alcohol ("Polyviol" W 28/20, Reference number 36 07 0459; Wacker Chemie GmbH. München 22, West Germany), 2.5 gm.; Lactophenol (50 gm. Phenol crystals in 50 m*l.* lactic acid), 30 m*l.*; Distilled water, 10 m*l.*

It may be noted that the preparation of this mountant may be speeded up by polymerizing the polyvinyl alcohol with a drop of formaldehyde solution before adding water (unpublished technique of Dr. S. K. BANERJEE).

P. alba was reared with moderate success on dead and partly decomposed leaves of American elm (*Ulmus americana* L.) and sugar-maple leaves (*Acer saccharum* L.). On the addition of yeast to the diet, however, the colonies multiplied much more rapidly, but with the yeast alone no satisfactory increase in numbers occurred. *P. alba* also avoided fungal mycelium in the same way as did *P. petterseni*.

It was also noted that, in rearing cells, *P. alba* will eat the eggs of its own species. On one occasion, during rearing in small cells, one of three adults present in a cell, laid six eggs. On the following day two of the adults were seen apparently feeding on these eggs, and after half an hour pits were observed on the tops of four eggs. The pits appeared to have been chewed out by the Collembola. On the third day, two of the eggs had vanished from the cell, and on the fourth day after oviposition the remaining four eggs had also disappeared. The usual food (yeast and partly decayed elm leaves) was present at all times. Similar occurences were observed in other rearing cells, confirming the egg-eating habit of this species. MACNAMARA (1924), BROWN (1954) and others have mentioned various carnivorous feeding habits among Collembola — on dead animal tissues, on other living Collembola and on nematodes — but, so far, none has been reported feeding on eggs of any kind, let alone on those of its own species.

6. Eggs

Eggs of *P. petterseni* were laid singly and scattered in the crevices of the plaster (if these were present), or on the smooth walls of the rearing cells. On deposition they were covered with a sticky fluid from the anus (see also DAVIS and HARRIS 1936). At room temperature (24 °C. approx.), the number of eggs laid by a single female varied from six to fifteen at a time. Each female oviposited several times during its life, but after the third oviposition no further records were kept. DAVIS and HARRIS (1936), however, reported the total number of eggs laid by one female throughout its lifetime as 45. The number of eggs laid per oviposition decreased with the temperature (see Table 1). At 4 °C. no oviposition occurred

Table 1. Number of eggs laid per oviposition by females of *Pseudosinella petterseni* and *P. alba* (number of females: 15, 13, 10 and 10 of the former, and 13, 10, 13 and 10 of the latter species at 24, 17, 11 and 4 °C., respectively).

Species	Temperature (°C.) 24	17	11	4
	No. of eggs			
P. petterseni				
maximum	15	10	7	0
minimum	6	5	4	0
mean	12.4	8.5	5.4	0
P. alba				
maximum	16	12	6	0
minimum	6	6	3	0
mean	9.5	8.0	4.0	0

On oviposition the eggs were spherical, smooth and white and measured 0.16 mm. in diameter. On the third day of incubation at 24 °C. the diameter increased to 0.189 mm. and hair-like outgrowths began to appear on the chorion. On the fourth day the 'hairy' covering became quite distinct. Such hair-like structures on the eggs of certain Collembola were observed well over a century ago by NICOLET (1842) who states that, "dans ce dernier cas les oeufs sont parfois velus; garnis de poils longs et serrés." No splitting of the chorion, such as that reported for other species of Collembola (cf. MARSHALL and KEVAN 1962,

Sharma and Kevan 1963a, b) has been observed in this species. There was no further increase in size.

Davis and Harris (1936) record that the eggs of this species hatched on the eighth day of incubation at 25 °C., and comparable results were obtained during the present study. At 24 °C. eggs took 7—9 days to hatch. A slightly lower percentage, however, hatched at 24 °C. than was reported by Davis and Harris (1936) for temperatures only one degree higher (88.3 as against 92%). A significant drop in the percentage of hatching was observed at lower temperatures, and, at 11 °C., only one-third of the eggs hatched. No hatching occurred at 4 °C. although considerable numbers of eggs were exposed to this temperature for up to three months. The optimum incubation temperature for this species appears to be 30 °C., at which all the eggs hatched in the minimum time (Table 2).

Table 2. Icubation period in days (means in parentheses) and percentage hatched for eggs of *Pseudosinella petterseni* and *P. alba* reared at different temperatures. [Number of eggs of former species incubated: 224, 206, 54 and 30, and of latter: 114, 80, 48 and 30, at 24, 17, 11 and 4 °C. respectively; figures for temperatures above 24 °C. from Davis and Harris (1936)]

Temperature (°C.)	Days required for hatching		Percentage eggs hatched	
	P. petterseni	*P. alba*	*P. petterseni*	*P. alba*
36.7	16		70	
34	11		100	
30	6		100	
25	8		92	
24	7—9 (7.6)	7—10 (8.3)	88.3	82.4
17	12—15 (12.2)	12—14 (13.03)	72.8	67.5
11	31—37 (34.0)	26—38 (31.2)	33.3	58.3
4	No hatching after 92 days	No hatching after 92 days	0	0

The chorion of eggs which failed to hatch became brown in colour.

The eggs of *P. alba* are laid in a similar scattered manner to those of *P. petterseni*. At 24 °C. females laid 6—16 eggs at a time. The numbers deposited at other temperatures are shown in Table 1. The number of ovipositions and the total number of eggs per female were not determined.

The eggs of *P. alba* when laid were similar to those of *P. petterseni*, but slightly smaller; they measured 0.14 mm. in diameter. On the second day of incubation at 24 °C. they increased to 0.16 mm., and on the third day the chorion became 'hairy' as in *P. petterseni* Again no subsequent increase in size was observed.

At 24 °C. eggs took 7—10 days to hatch. The incubation period increased as the temperature decreased and was 26—38 days at 11 °C. When thirty eggs were kept at 4 °C. none hatched after being exposed to this temperature for three months. Lowering the temperature also affected the percentage of eggs hatching. There was a decrease of 24.1 in the percentage of eggs hatching when the temperature was lowered from 24 to 11 °C. (Table 2). Optimum conditions for incubation were not determined in this species, but temperature requirements are apparently similar to those of *P. petterseni*, although lower temperatures appear to be somewhat less lethal.

Eggs kept at 24 °C. which failed to hatch turned violet ten days after oviposition and a similar colour change in dead eggs was also observed at other temperatures. The colour of the chorion in the dead eggs of the two species thus shows a marked difference.

7. Postembryonic Development

Young *P. petterseni* reared at 24 °C. averaged 0.41 mm. in length on hatching, their mean antennal length being 0.14 mm., an average ratio of 2.87 : 1 (i. e. nearly 3 : 1). Increases in body and antennal lengths were relatively uniform until the fourth moult. After the fifth and sixth moults the increase in the length of the antennae was significantly greater in relation to the body length. Adult females at first oviposition averraged 1.17 mm. in length, the mean length of their antennae being 0.48 mm., an average ratio of 2.34 : 1 (i. e. less than 2.5 : 1) — see Table 3. Such changes in the length of the antennae relative to the body are well known in Collembola. FOLSOM (1919), for example, states that, in *Tomocerus vulgaris* (TULLBERG), "as the individual grows there are changes in the relative lengths of the segments of the body and those of the appendages".

Juveniles of *P. petterseni* were white in colour without trace of pigment. No change in colour took place throughout life. The largest individual measured was 1.41 mm. MILLS (1934) and MAYNARD (1951), however, record a maximum length of 1.5 mm. for North America; GISIN (1960) cites 1.0 mm. for European material.

Since it is difficult to determine when male Collembola are sexually mature, the period required for postembryonic development was determined for females only, measuring the time from the data of hatching until the first oviposition occurred Males possibly matured a little sooner than did females.

At 24 °C. there were found to be five to six moults before the first oviposition. DAVIS and HARRIS (1936), using DYAR's factor, also calculated that there were six instars at 30 °C. before the first oviposition The later stadia (5 and 6) took longer to complete than did earlier ones (see Table 4), probably due to their increasing sexual maturity.

Young individuals of *P. alba* measured 0.45 mm. in length on hatching. In the first instar the young were dull white in colour, but in the second they became dirty white and shining. The colour became darker grey to blackish in successive instars. The length

Table 3. Length (in mm.) of body (b) and antennae (a) of seven individuals (A—G) of *Pseudosinella petterseni*, reared at 24 °C. (Measurements for first instar were on hatching; those for other instars, immediately after ecdysis)

Instar		Individuals A	B	C	D	E	F	G	Average ratio b : a
					Length (mm.)				
1	b	0.40	0.40	0.43	0.43	0.43	0.43	0.40	
	a	0.13	0.13	0.16	0.16	0.16	0.16	0.13	
2	b	0.56	0.51	0.56	0.56	0.54	0.51	0.59	
	a	0.21	0.18	0.21	0.21	0.18	0.18	0.21	
3	b	0.91	0.67	0.78	0.70	0.70	0.59	0.75	2.87 : 1
	a	0.32	0.21	0.27	0.21	0.21	0.21	0.27	(2.53 : 1—3.30 : 1)
4	b	1.13	0.81	0.94	0.91	0.81	0.67	0.89	
	a	0.37	0.29	0.32	0.32	0.29	0.21	0.32	
5	b	1.21	1.08	1.08	1.02	0.89	0.81	0.99	
	a	0.40	0.37	0.37	0.35	0.32	0.32	0.35	
6	b	1.24	1.18	1.08	1.08	0.94	0.89	1.08	
	a	0.51	0.48	0.45	0.45	0.40	0.40	0.48	2.34 : 1
7	b	1.24	1.24	1.24	1.24	1.02	1.05	1.21	(2.20 : 1—2.40 : 1)
	a	0.51	0.51	0.51	0.51	0.43	0.45	0.51	

of the females at first oviposition averaged 0.91 mm. The longest individual measured was 1.0 mm , agreeing with the size given by MILLS (1934), MAYNARD (1951) and GISIN (1960).

Table 4. Duration in days (means in parentheses) for each of the first six instars of *Pseudosinella petterseni* and *P. alba*. (Number of individuals involved of the former: 28, 22 and 20; and of the latter: 24, 18 and 23, at 24, 17 and 11 °C. respectively)

Species	*P. petterseni*			*P. alba*		
Temperature (°C.)	24	17	11	24	17	11
Instar	Number of days					
1.	3—5 (3.8)	5—9 (6.8)	12—19 (15.6)	4—7 (5.2)	5—10 (7.2)	10—13 (11.6)
2.	3—6 (3.7)	4—9 (6.2)	11—20 (15.4)	5—7 (5.5)	5—11 (6.7)	9—14 (11.0)
3.	3—7 (3.8)	3—7 (5.6)	10—18 (13.1)	4—9 (6.1)	5—12 (7.4)	9—17 (10.8)
4.	3—6 (4.5)	6—14 (9.1)	12—18 (15.6)	5—7 (6.0)	5—13 (8.5)	8—17 (12.0)
5.	5—9 (5.5)	6—17 (12.5)	13—21 (16.5)	4—10 (6.3)	6—18 (11.2)	12—21 (16.0)
6.	4—8 (5.3)	10—13 (10.9)	12—17 (13.0)	5—10 (6.5)	10—19 (14.7)	11—20 (16.1)

As in *P. petterseni* there were five to six moults at 24 °C. before the first oviposition. The duration of each stadium, however, was more uniform since the earlier instars developed more slowly (see Table 4). Five individuals out of twenty-four reared at 24 °C. oviposited in the sixth instar and eight in the seventh. The remaining individuals did not oviposit and were probably males.

8. Effect of Temperature on Postembryonic Stages

Temperature had a marked effect, not only on the incubation period and percentage of eggs hatching (see above), but also on survival, oviposition and postembryonic development.

Ten adult specimens of *P. petterseni* were kept first at 4 °C. for one week and then at 0 °C., but within a period of thirty days at the latter temperature all had died At 4 °C. adults survived for more than two months but they did not oviposit.

Table 5. Total number of days (means in parentheses) from hatching until first oviposition in *Pseudosinella petterseni* and *P. alba*. (Number of individuals of the former species: 15, 13 and 10, and of the latter: 13, 10 and 13, at 24, 17 and 11 °C., respectively)

Temperature (°C.)	30	24	17	11
		Number of days		
P. petterseni	10.5*	27—29 (27.9)	39—61 (48.6)	87—112 (99.7)
P. alba	—	32—45 (37.5)	46×—63 (59.2)	83—93 (88.7)

* From DAVIS and HARRIS (1936).
× A single individual which never oviposited is included here since it was the only one which reached the seventh instar in so short a time.

The duration of the postembryonic development decreased as the temperature increased (see Tables 4 and 5). At 24 °C., 27 to 29 days were required before the first oviposition occurred, but at 30 °C. DAVIS and HARRIS (1936) have stated that only 10½ days were needed to complete postembryonic development (data for other temperatures are not given by these authors). At 11 °C. it was found that between 87 and 112 days were necessary, the average being nearly 100 days.

The above observations indicate that *P. petterseni* prefers warm temperatures. The optimum for this species is probably 30 °C. because at this temperature, in the laboratory, the embryonic and postembryonic development was found so be the most rapid, although the information regarding the latter is not available for higher temperatures. At 30 °C. the entire life cycle could be completed in as little as 16½ days. At 24 °C. it averaged 35½ days and at 11 °C. the average figure was 133.7 days. *P. petterseni* does not seem to be able to survive freezing, but it can tolerate low temperatures (at least down to 4 °C. — see above). BELLINGER (1954), in Connecticut, obtained specimens of adult *P. petterseni* in soil samples taken in winter about a foot below the surface, suggesting that this species can probably survive low temperatures in nature by migrating to the deeper layers of the soil. There are, in fact, indications that the species survives the Canadian winter in this manner.

As in *P. petterseni*, temperature had a marked effect on *P. alba*, not only on the incubation period and percentage of eggs hatching, but also on oviposition, survival and postembryonic development. Tolerance of low temperatures by adults is greater in *P. alba* than in *P. petterseni*. Of ten individuals kept first at 4 °C. for about a week and then at 0 °C., only three died within a period of two months at the latter temperature (when the experiment was concluded). No eggs were laid by these individuals, however.

The duration of the postembryonic period increased with a decrease in temperature for this species also (Tables 4 and 5). At 24 °C. a rather longer time elapsed than in *P. petterseni* before the first oviposition. The majority of the 13 individuals referred to on Table 5 laid eggs about 37 days after hatching, that is, after a considerably longer period than in *P. petterseni*. Two of the individuals which first laid eggs in the sixth instar required only 32 days, however, and one of those which did not oviposit until the seventh instar required as much as 45 days to mature.

At 17 °C. *P. alba* again required rather longer to mature than did *P. petterseni* (an average of 59.2 as against 48.6 days), but at 11 °C. development was a little less retarded than in that species (an average of 88.7 as against 99.7 days — see Table 5). *P. alba* thus appears to be a slower maturing species than *P. petterseni*, but one which is less adversely affected by lower temperatures, for, although at 24 °C. the average time needed to complete the life-cycle was nearly 46, as against 35½ days, at 11 °C. the number of days required was only 120, as against 134 for *P. petterseni*.

9. Field Observations

BELLINGER (1954), working in Connecticut, reported both *P. petterseni* and *P. alba* in his samples, but he found that the two species occurred in different areas. *P. alba* was found only under stands of White and Red pines and Hemlock; *P. petterseni* was found in uncultivated areas with some young White pines. In the Morgan Arboretum, Ste. Anne de Bellevue, Quebec, however, both species occurred together in the soil investigated.

Neither species proved to be very abundant compared with many soil micro-arthropods, but from the 20 samples taken between June and September, 1961, 47 adult *P. petterseni* and 152 *P. alba* were obtained (Table 4). Further sampling would be necessary for statistical analysis, but it is interesting to note that there appeared to be a tendency for *P. alba* to be more abundant and to be the commoner species under cooler conditions.

For the methods of sampling and temperature recording used, see SHARMA and KEVAN (1963a).

Table 6. Numbers of adult *Pseudosinella petterseni* and *P. alba* extracted from five samples per month during June to September, 1961

Month	Mean soil temperature (°C.)	Numbers extracted	
		P. petterseni	*P. alba*
June	16.1	18	40
July	20.6	15	29
August	21.6	5	17
September	14.2	9	66
Totals		47	152

10. Other Observations

P. petterseni, although devoid of eyes, is very sensitive to light. Those in laboratory cultures became extremely agitated and tried to escape from lighted areas when the lid of the culture jar was removed under artificial light. Negative phototaxis is strong and is doubtless the principal factor in compelling the species to seek out its appropriate habitat.

P. petterseni is also very sensitive as regards oviposition. A single female apparently would not oviposit more than twice or thrice in the same culture jar (although this was as much as 6.0 cm. in diameter), no matter how long it was allowed to live there. On being transferred to a new jar, however, the same female would oviposit three or four days later. It might be possible that the continuous presence of yeast in the original jar and its fermentation inhibit further oviposition.

11. Conclusion

P. petterseni and *P. alba* appear to differ to some extent in their food and habitat preferences, in their tolerance of lower temperatures and in their rate of embryonic and postembryonic development. The differences and similarities in their life histories are summarized in Table 7. The principal differences seem to be that, while *P. petterseni* can thrive satisfactorily on vegetable matter or yeast alone, *P. alba* cannot do so, that *P. petterseni* develops more rapidly at higher temperatures but *P. alba* (with the possible exception of the last pre-adult instar) is less retarded at lower ones, and that *P. petterseni* cannot tolerate freezing, whereas *P. alba* can do so. The percentage of eggs hatching at lower temperatures (11 °C.) is 25 per cent. more in *P. alba* than in *P. petterseni*. A reduction in temperature from 24 to 11 °C. more than doubles the period of postembryonic in *P. alba*, but more than triples it in *P. petterseni*. This, as much as habitat, may explain the greater abundance of *P. alba* in south-eastern Quebec as compared with more southerly stations.

From laboratory results and records of field temperatures it seems likely that, in southwest Quebec, both species of *Pseudosinella* may have approximately three generations a year. Eggs laid in September by females of either species could hatch in October, but the progeny are not likely to mature before the melting of the snow in the following spring. Between May and September there may conceivably be two more generations of each species, *P. petterseni* overtaking the more cold-tolerant *P. alba* as the summer temperatures increase, and then in turn being overtaken by the latter species with the approach of cooler conditions.

Table 7. Comparison pf *Pseudosinella petterseni* and *P. alba*. (Figures in parentheses are averages)

	P. petterseni	*P. alba*
Size of adult (mm.)	1.41—1.5	0.91—1.0
Colour of adult	Dull white	Variable, usually shining dirty white, grey or black
Habitat	Under logs or stones, in mull soil and litter, in greenhouses, in caves and in nests of ants.	Under stones on sandy soil and surface litter under conifer and maple stands, and in caves.
Food	A wide range of living and decaying vegetable matter; yeast alone in the laboratory.	Decaying leaves with yeast; possibly some animal matter since eggs of own species may be eaten.
Number of eggs per oviposition (24 °C.)	6—15	6—16
Size of egg (mm.)	0.16	0.14
Incubation period at 24 °C. (days)	7—9 (7.6)	7—10 (8.3)
Incubation period at 11 °C. (days)	31—37 (34.0)	26—38 (31.2)
Percentage hatching at 24 °C.	88.3	82,4
Percentage hatching at 11 °C.	33.3	58.3
Size of young on hatching (mm.)	0.41	0.45
Number of moults before oviposition	5—6	5—6
Duration of first instar at 24 °C. (days)	3—5 (3.8)	4—7 (5.2)
Duration of first instar at 11 °C. (days)	12—19 (15.6)	10—13 (11.6)
Duration of sixth instar at 24 °C. (days)	4—8 (5.3)	5—10 (6.5)
Duration of sixth instar at 11 °C. (days)	12—17 (13.9)	11—20 (16.1)
Duration of postembryonic development at 24 °C. (days)	27—29 (27.9)	32—45 (37.5)
Duration of postembryonic development at 11 °C. (days)	87—112 (99.7)	83—93 (88.7)
Average time to complete life-cycle at 24 °C. (days)	35.5	45.8
Average time to complete life-cycle at 11 °C. (days)	133.7	119.9
Percentage survival of adults after 30 days at 0 °C. (10 individuals in each case)	0	70

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13. Summary

Pseudosinella petterseni and *P. alba* are two soil- and litter-inhabiting Collembola commonly found under stones and logs, in caves and elsewhere in many parts of the world. Both species have been extracted together from soil and litter samples in southern Quebec.

The male genital plate of each species has been described for the first time, that of each species is characteristic in shape and chaetotaxy. A spermatophore-like structure is described in the ejaculatory duct of both species; these structures are generally similar in the two species but differ considerably in detail.

According to the literature, *P. petterseni* is an unspecialized feeder. In the laboratory it has been reared on yeast alone. For *P. alba*, however, partly decayed leaves had to be added to the diet in order to establish a thriving colony. Both species avoid fungi. *P. alba* will eat the eggs of its own species.

In both species the eggs are smooth and white and are laid in a scattered manner. After a few days they become covered with a 'hairy' coating. Eggs of *P. petterseni* develop more rapidly at higher, and more slowly at lower, temperatures than do those of *P. alba*; in the latter species also, a higher proportion hatch a lower temperatures.

In each species there are five or six moults before maturity is reached. The average life cycle of *P. petterseni* is completed in 35½ days at 24 °C. and 134 days at 11 °C.; that of *P. alba* is completed in 46 days at 24 °C. and 120 days at 11 °C. Adults of both species survive at 4 °C. but do not reproduce; at 0 °C. *P. alba* can survive, but *P. petterseni* can not. There are probably about three generations of each species per year in south-western Quebec.

13. Zusammenfassung

Pseudosinella petterseni und *P. alba* sind zwei im Boden bzw. in der Streu lebende Collembolen, die gewöhnlich unter Steinen oder Holzblöcken und in Höhlen in vielen Teilen der Welt anzutreffen sind. Beide Arten wurden miteinander von Streu- bzw. Bodenproben aus Süd-Quebec ausgelesen.

Die männliche Geschlechtsplatte beider Arten wurde das erste Mal beschrieben; dieselbe ist bei beiden Arten charakteristisch sowohl in der Form wie in der Borstenverteilung. Eine spermatophorartige Struktur im Ductus ejaculatorius beider Arten wurde beschrieben; diese Strukturen sind im allgemeinen einander ähnlich, sie weisen jedoch bedeutsame Unterschiede in den Einzelheiten auf.

Der Literatur gemäß, ist *P. petterseni* auf keine besondere Ernährungsart spezialisiert. Im Laboratorium wurde sie mit Hefe allein aufgebracht. Demgegenüber mußten der *P. alba* teilweise verfaulte Laubblätter zugeführt werden, um eine gut gedeihende Kolonie zu erhalten. Pilze werden von beiden Arten gemieden. *P. alba* verzehrt die Eier der eigenen Art.

Die Eier beider Arten sind glatt und weiß, sie werden verstreut gelegt. Nach einigen Tagen werden sie mit einer „haarigen" Hülle überzogen. Die Eier von *P. petterseni* entwickeln sich schneller bei höherer und langsamer bei niedrigerer Temperatur als die von *P. alba*; auch wurde bei der letzteren Art ein größerer Teil bei niedriger Temperatur ausgebrütet.

Bei jeder Art gehen fünf oder sechs Häutungen vor sich, bevor die Reife erreicht ist. Die durchschnittliche Lebensdauer von *P. petterseni* beträgt 35½ Tage bei 24 °C und 134 Tage bei 11 °C; bei *P. alba* sind es 46 Tage bei 24 °C und 120 Tage bei 11 °C. Ausgewachsene Individuen beider Arten bleiben noch bei 4 °C am Leben, eine Fortpflanzung findet jedoch nicht mehr statt, *P. alba* bleibt bei 0 °C noch am Leben, *P. petterseni* jedoch nicht mehr. Es sind anscheinend jährlich etwa drei Generationen von jeder Art im südwestlichen Quebec vorhanden.

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